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Raceway systems for the culture of shrimp

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THE RESEARCH EFFORT of the Shrimp Aquaculture Investigation at the Galveston Laboratory of the National Marine Fisheries Service has been dedicated to providing basic background information needed for commercial culture of penaeid shrimp. Recently, an additional commitment has been made: that of providing the basic knowledge necessary to raise shrimp commercially in closed raceway systems. By exercising a high degree of environmental control in these systems, it has been possible to rear exceptionally high densities of shrimp.

While engineering know-how is being applied in an experimental closed raceway system, some basic problems, which contribute to the high costs of production, still exist. We find that the biggest stumbling blocks are still the lack of basic biological knowledge of the shrimp. Key problem areas are reflected by the project titles in our Aquaculture Investigation: Nutritional Studies, Sexual Maturation, and Shrimp Diseases. In the fourth project, Intensive Culture, we make use of research results from the other three projects in systems designed to maintain optimum conditions for rapid growth.

The complex nutritional problems involved in the formulation of feeds for penaeid shrimp are still a major factor limiting the profitability of shrimp culture. Although shrimp can be raised to a commercial size in semi-natural ponds with relatively small amounts of feed (when natural foods are abundant), feed consumption in tanks is much greater. For example, eight to ten lb of our control diet are required to produce one lb of shrimp of marketable size when that diet is the only food available.

Both the quality and quantity of protein in a diet have pronounced effects on growth rates of shrimp. Although growth has generally been better with protein levels of 50 - 60 per cent, diets of 25 per cent protein composed of an appropriate balance of amino acids may produce better growth than a poorly balanced diet with 50 per cent protein.

Since ingredients with a high protein content are expensive, the nutritional problems are intermeshed with economic problems such as feed conversion rates, and the length of time facilities are in use to produce a crop of shrimp. A related problem is that when inexpensive foods are used, and therefore food conversion rates are poor, excessive quantities of organic material are introduced into culture systems with the feed, thereby complicating the waste removal problems. As feed costs have risen during the last year, several pilot commercial operations working in outdoor ponds have begun feeding rations with lower protein content (15-20 per cent) than those used earlier (25-30 per cent) in an effort to reduce feed costs. The effects of this change have not been evaluated.

Interestingly enough, we still may not have found the best means of presenting food to the shrimp. Although considerable effort has gone into developing appropriate binders, attractants and shapes, we still occasionally make modifications which result

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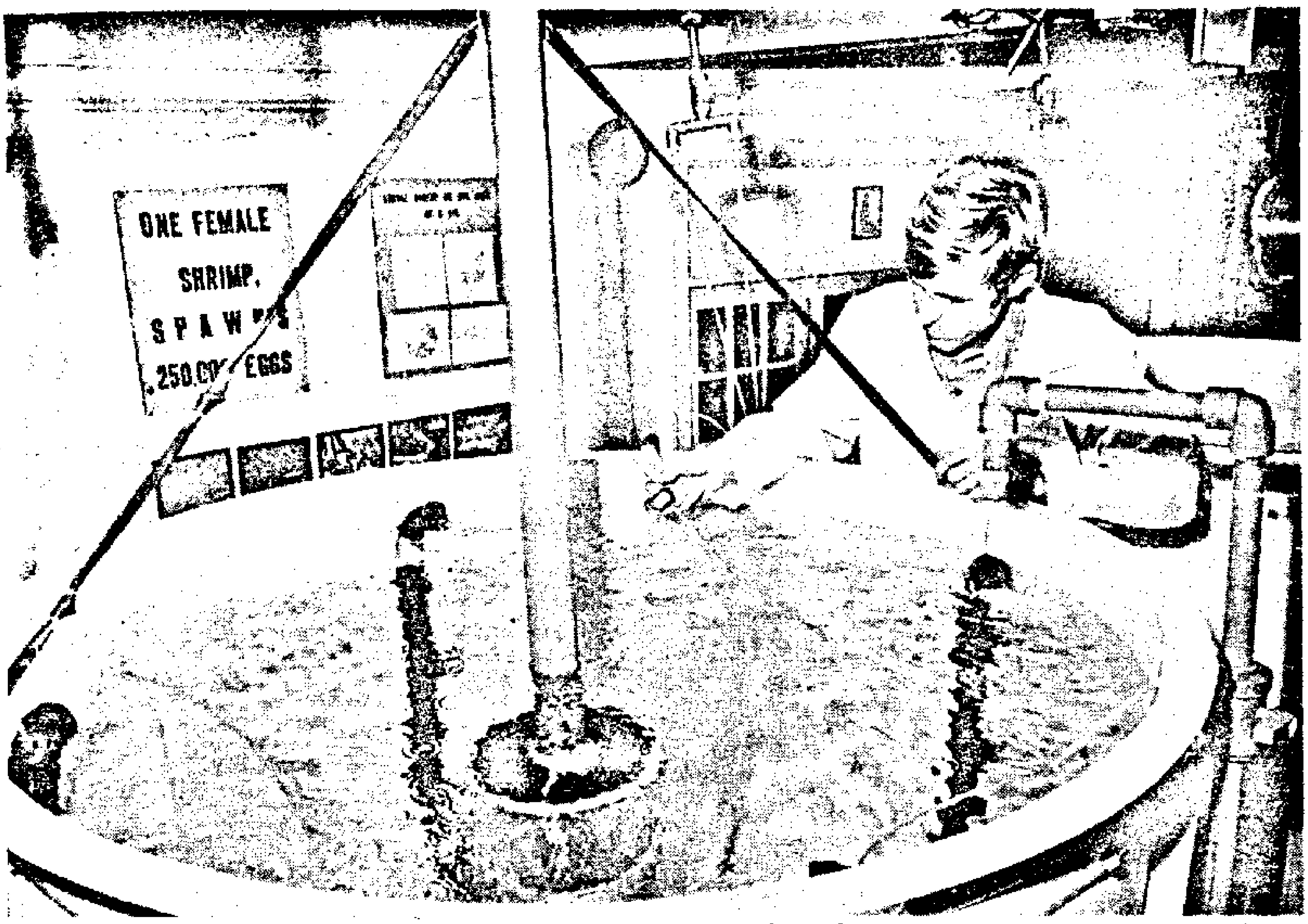


Tank used for rearing penaeid shrimp from egg to postlarval stage.

in improvements in growth and survival rates far surpassing those resulting from modi fication of the nutritional components. An example of this occurred recently when we found that finely ground particles of our extruded feed were superior to the same feed in flake form for postlarvae, apparently because the fine particles were distributed more uniformly through the water column.

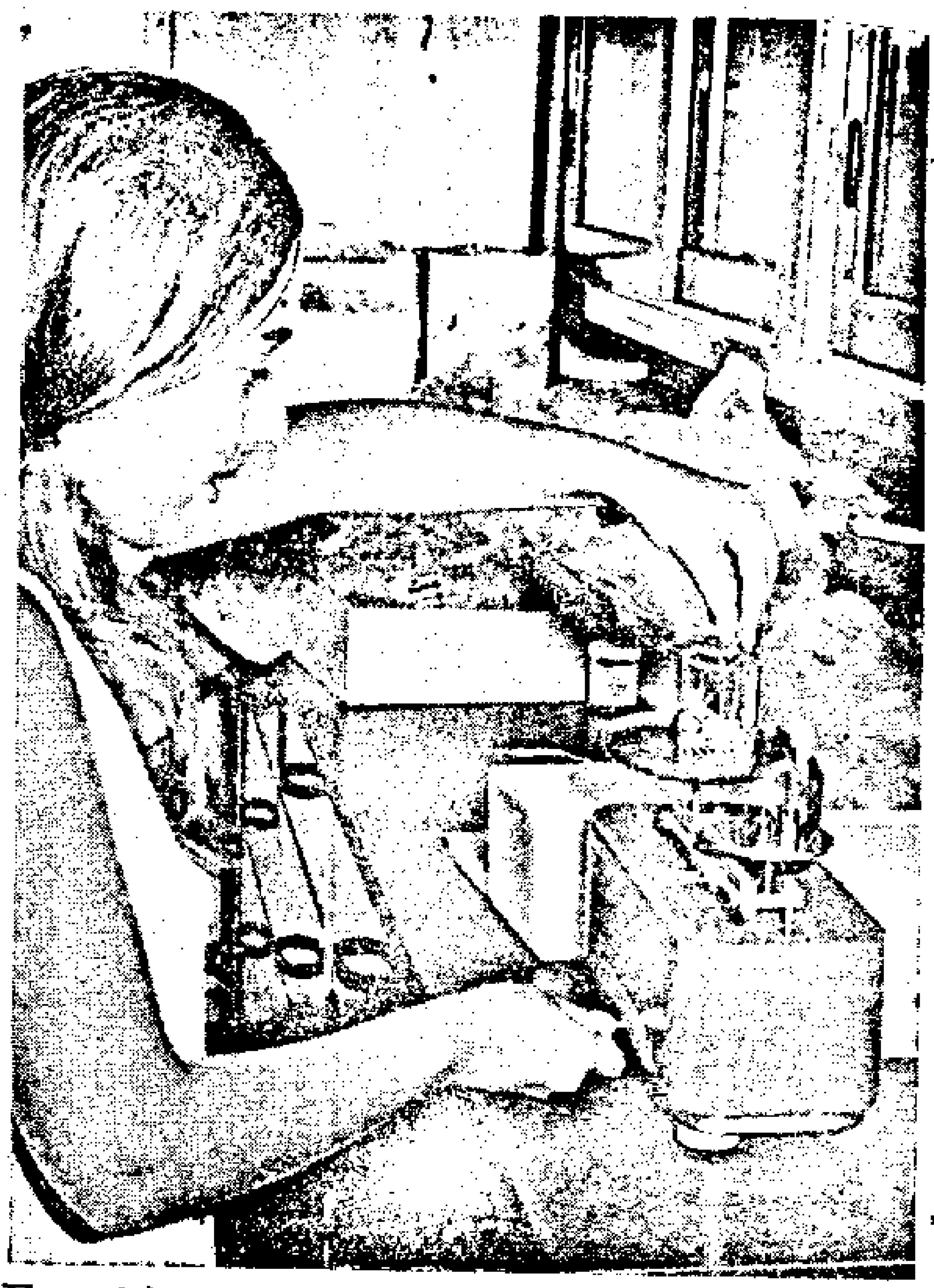
Our control diet, which contains ingredients costing about 13 cents a lb, is now available on a semi-commercial basis. We are encouraging other research institutions to test this feed on a comparative basis with their own feeds.

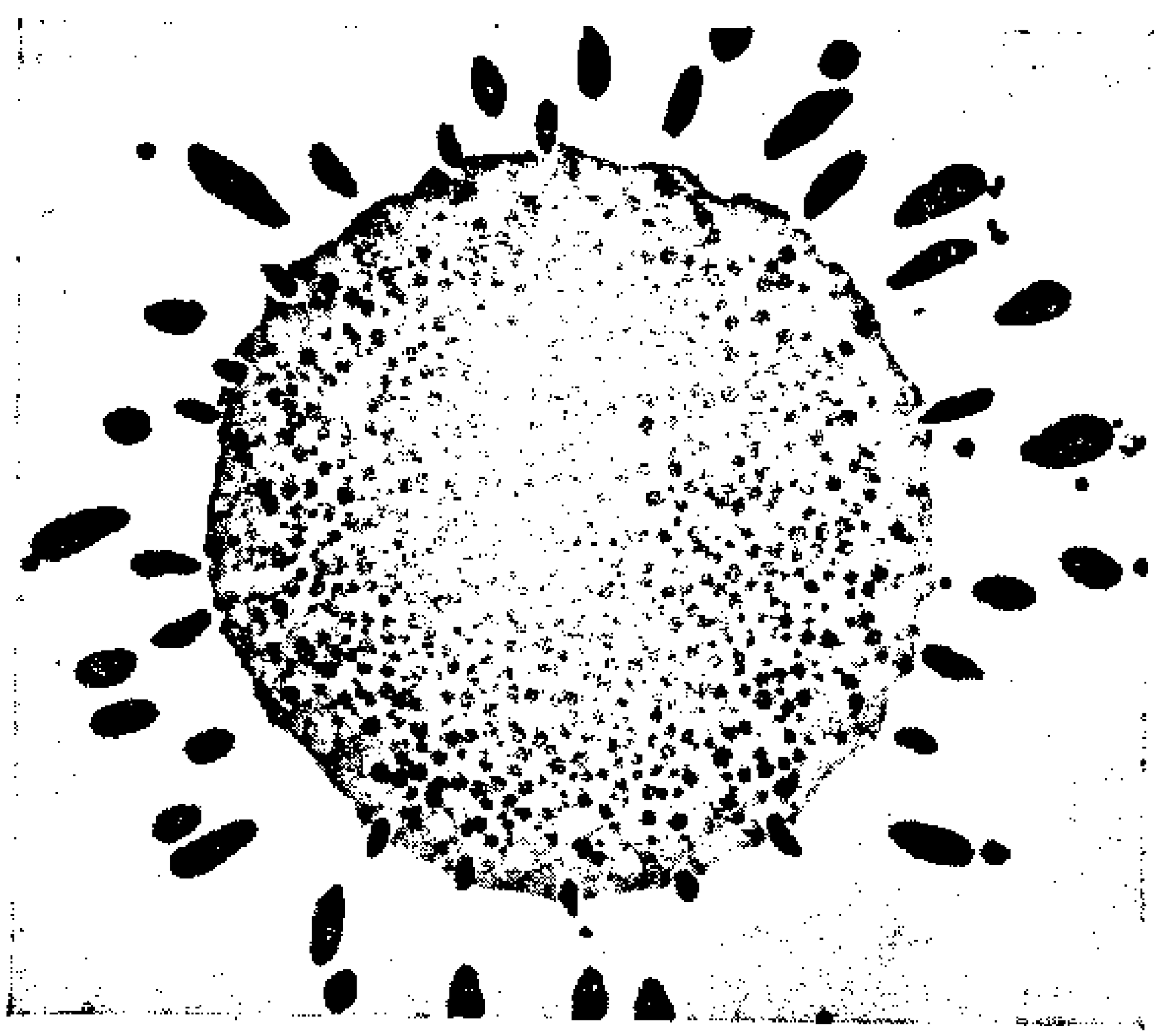
Preparatory to studies of the effectiveness of certain drugs in the control and treatment of shrimp diseases, the drugs are evaluated with respect to their effects on growth and survival of normal shrimp. Comparisons of the growth of shrimp fed several different concentrations of oxytetracycline and furazolidone with their food have been made. Both drugs are potentially useful for treatment of shrimp diseases. Increases in the rates of growth were observed at some concentrations of oxytetracycline. Although a similar response to some antibiotics occurs in other animals, the reasons are poorly understood.

Maturation

Our failure to complete the life cycle of penaeids in captivity is still a major handicap to overcome before true domestication and selective breeding are possible.

Although laboratories in Mexico and Tahiti have been successful in inducing the sexual maturation and spawning of certain species of captive shrimp, the species native to the Gulf of Mexico have not matured and spawned in captivity. Even though we have worked toward duplication of the offshore environment where shrimp normally mature and spawn, the experimentation we have done with environmental manipulation over the last few years has been unsuccessful in inducing maturation of the females.





Above. This photomicrograph of a shrimp egg immediately after spawning shows the action of the cortical rods.

Left. Feeds tested during nutritional studies are evaluated in terms of long-term growth, survival and conversion rates in tanks where little natural food is available.

For this reason we have initiated a more basic approach to the reproductive problem. This approach involves three major steps:

1. The description of the basic reproductive processes in wild penaeid shrimp utilising light and electron microscopy.

2. A comparison of these developmental processes in wild shrimp with those of experimental animals being held under defined environmental conditions. Abnormal development will be pinpointed with reference to the shrimp's environment and nutrition so that appropriate adjustments can be made to encourage normal sexual development.

3. Definition of the precise conditions and feeds required to mature and spawn captive shrimp.

Sources of hormones

Several related topics are being investigated as part of this work. The first is a study of the endocrinology of shrimp. This research includes studies of the effects of eyestalk (and consequently X gland) ablation as well as the isolation and identification of key hormones and the manipulation of the endocrine balance by injection of crustacean hormones. A search for economical sources of useful hormones in other crustaceans is underway. To date, these techniques have been used successfully in inducing ovarian development to the ripe stage, but the shrimp have not yet continued to the point of normal spawning.

Techniques for fertilisation of shrimp eggs removed from a female with sperm from a male are being developed. The fertilisation of shrimp eggs *in vitro*, which has been accomplished successfully on several occasions, offers potential for fertilisation of eggs without normal spawning or of hybridisation between species which do not mate.

As research on the basic histology and histopathology of penaeid shrimp is being completed, more emphasis is being placed on the recognition, prevention and treatment of shrimp diseases. A number of new diseases have been described and experimental evidence of their effects on shrimp is being collected. Viral, bacterial and fungal pathogens have all been demonstrated in the penaeid species now being cultured. Methods used for the culture and identification of pathogens are those developed by other research teams studying the disease organisms. Where necessary, techniques are modified for our purposes.

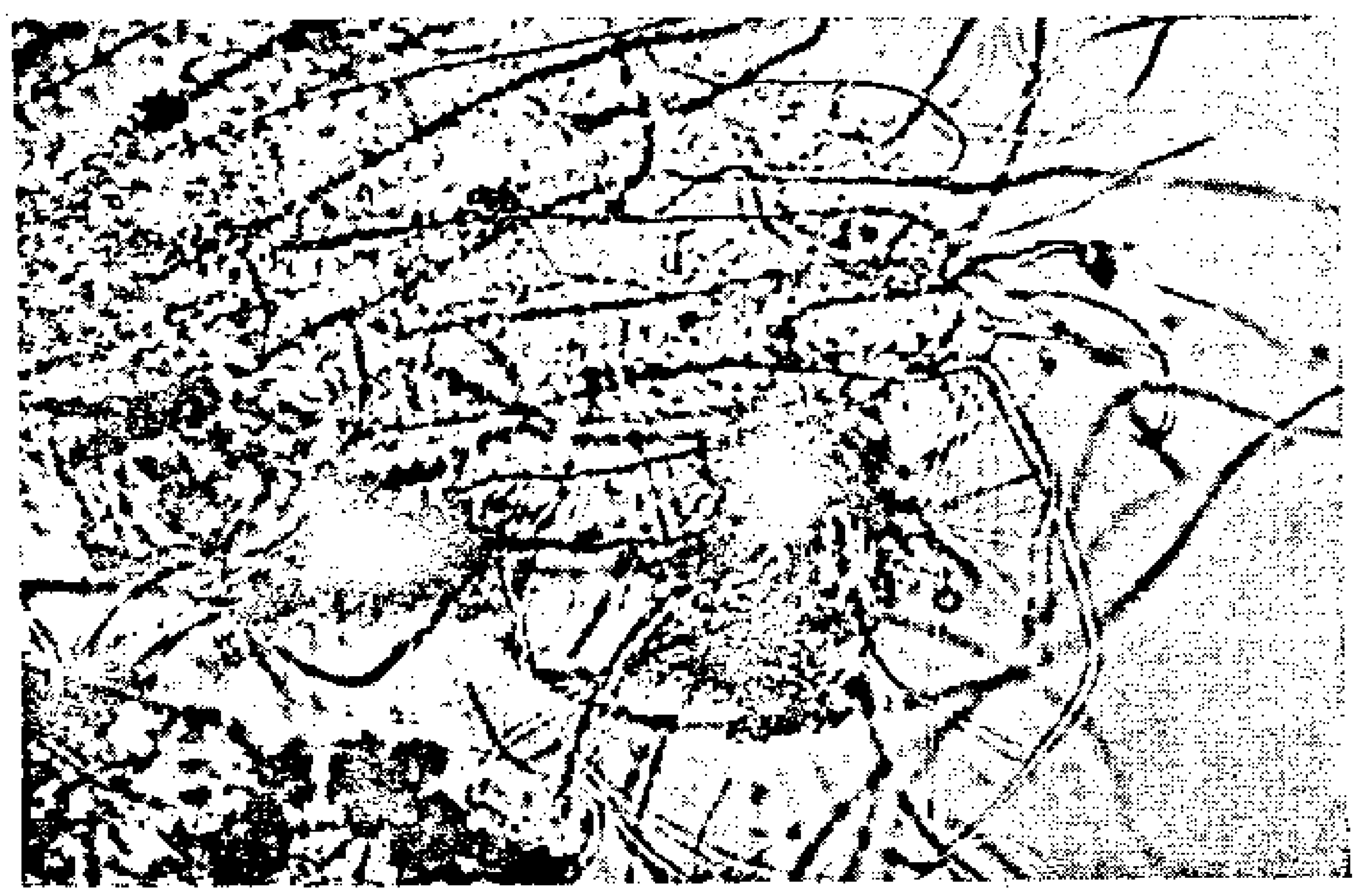
Density stresses

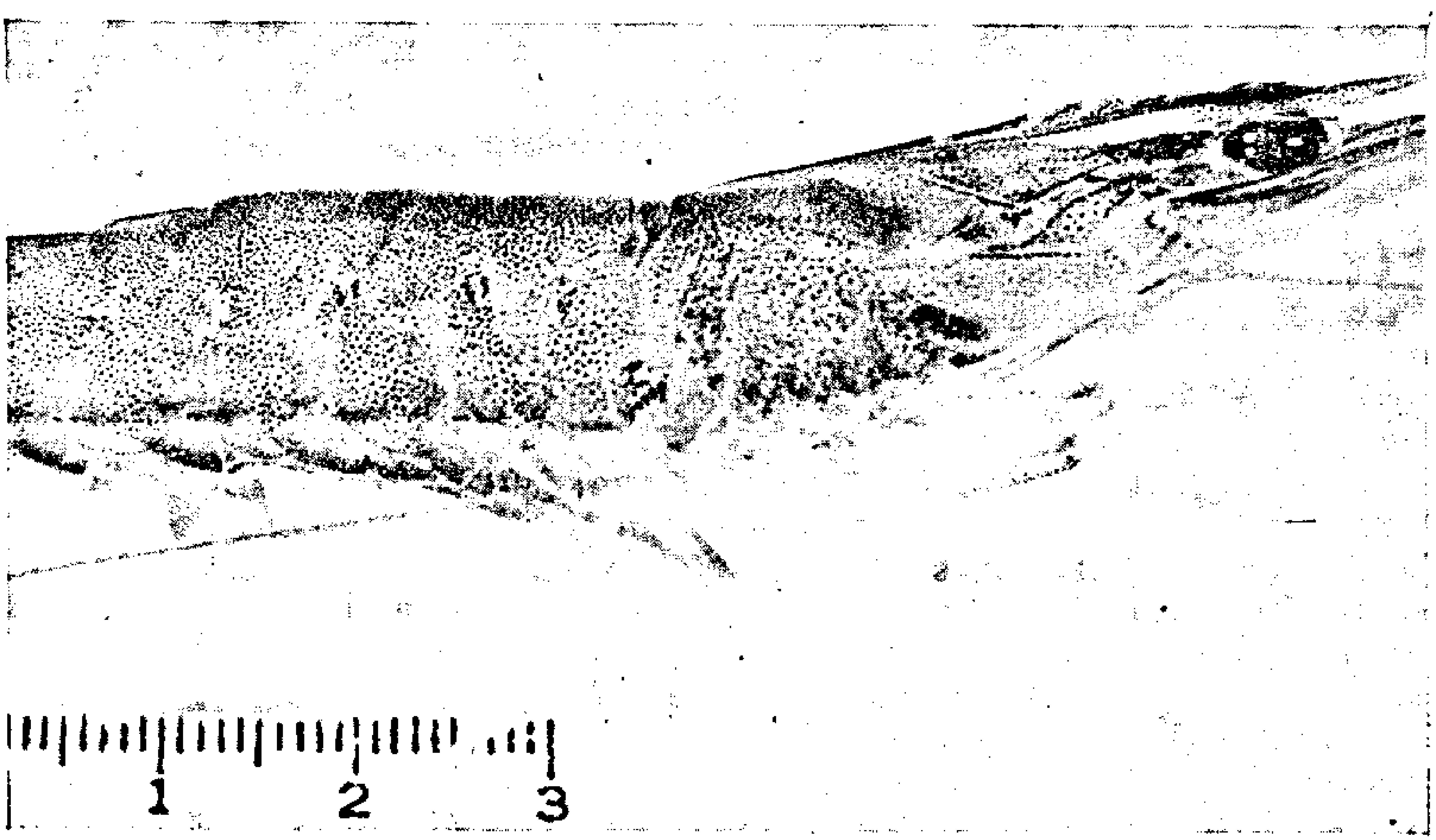
Although wild shrimp have many diseases and parasites, the effects of these diseases on wild shrimp or on shrimp held at low densities in ponds are not apparent. However, as densities are increased in culture situations, many stresses occur. In the presence of these stresses, mortalities associated with disease are apparent. As is frequently the case with other animals, the synergistic effects of diseases and environmental or nutritional stresses cause mortality when neither, by itself, is harmful enough to cause death.

The use of closed raceway systems and controlled environments for shrimp culture presents many opportunities for prevention and treatment of diseases which do not exist in semi-natural ponds. In controlled environments, it is possible to change temperature or salinity rapidly or to replace the water within a short time. Chemical treatment of the water in a controlled fashion for either short or long periods is feasible in

Below. A shrimp infected by gill disease. This is caused by a filamentous bacterium and eventually causes death by suffocation. Note the darkened gill area resulting from accumulation of debris.

Right. Filamentous bacterium attached to gill processes. Note the clumps of debris entangled in the filaments. The bacterium has not been positively identified.





the closed raceway systems. A number of antibiotics are being examined to determine their effects on:

1. Normal shrimp when administered orally or added to the water; and
2. Diseased shrimp and freeliving forms of shrimp parasites.

The treatments used in fish disease prevention and control frequently appear to be suitable for shrimp disease control as well.

High density culture

From a behavioural point of view, penaeid shrimp are moderately well-suited for culture at high densities, they will tolerate heavy crowding when properly fed and can be encouraged to utilise the water column by maintaining water currents within an enclosure. The growth and survival obtained as well as the total biomass we have supported in our closed raceway systems all have been encouraging.

We have reached a total biomass of 750 g/m² in our raceways, but have not surpassed this level to date because of the accummulation of wastes in our systems. Generally, the methods developed for treatment of domestic sewage are well suited to the removal of wastes from water in closed culture systems. However, the costs of this treatment are critical in an aquaculture system, and much of our effort has been directed toward determining the most efficient techniques for use with seawater containing the particular concentrations of wastes encountered in culture systems.

Based on results obtained to date, a combination of four methods of water treatment seems most practical. The four methods are:

1. Aeration;
2. Growth of algae;
3. Removal of particulate matter through sedimentation;
4. Biological filtration.

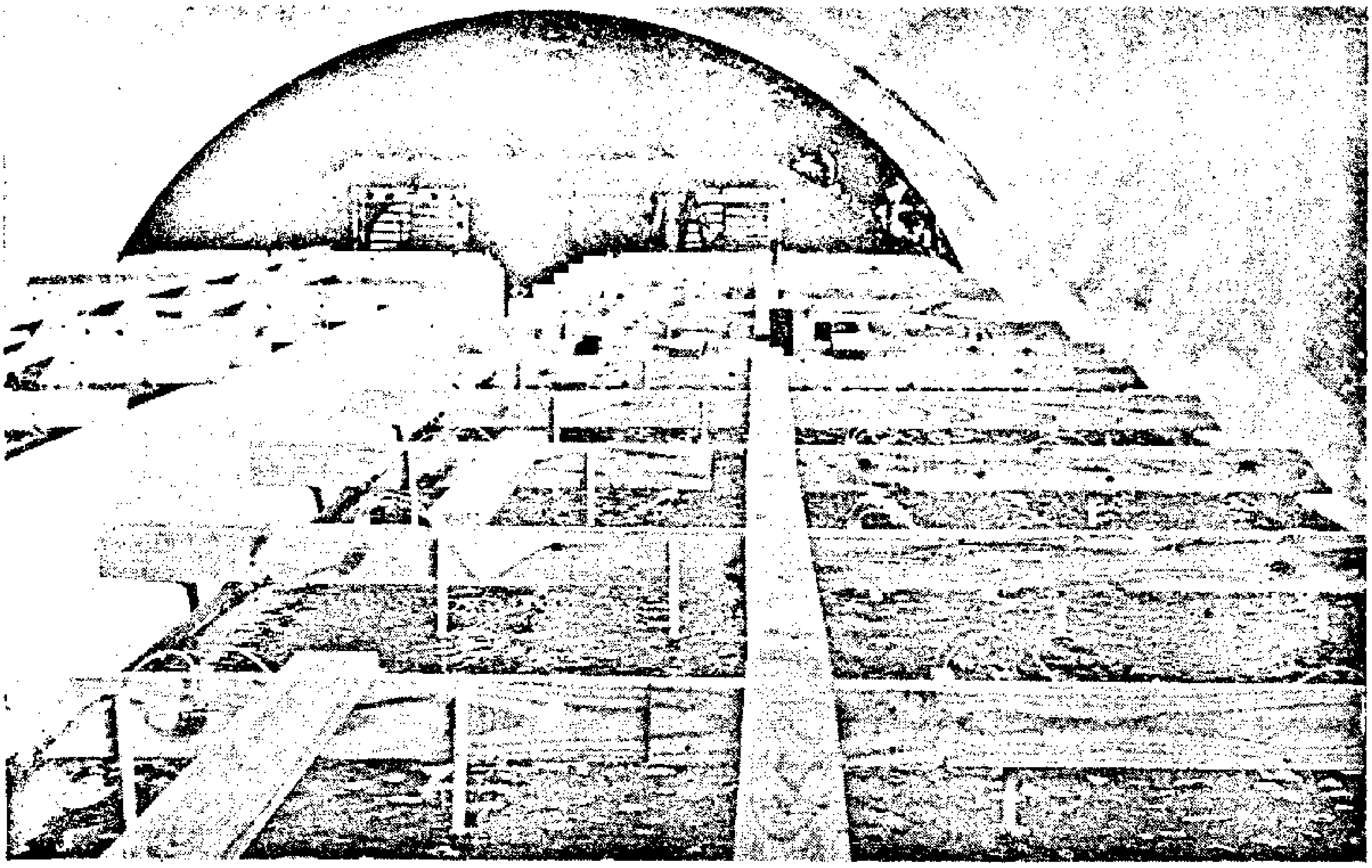
The heavy aeration used in our systems serves to insure high oxygen levels throughout the system thus encouraging rapid oxidation of wastes. Also the aeration removes some undesirable dissolved gases directly from the water by air stripping, and, when our airlift pumps are fitted with elbows, causes circulation of the water mass.

Growth of algae in the greenhouse-covered system serves primarily as a means of removing nitrates and phosphates from the water, although other substances may also be removed by the plants. The algal cells, whether benthic or planktonic, are eventually removed from the system as part of the particulate matter. To date, we have not attempted to control plant species growing in the system; however, this additional refinement in our system could potentially permit the simultaneous production of economically valuable algae.

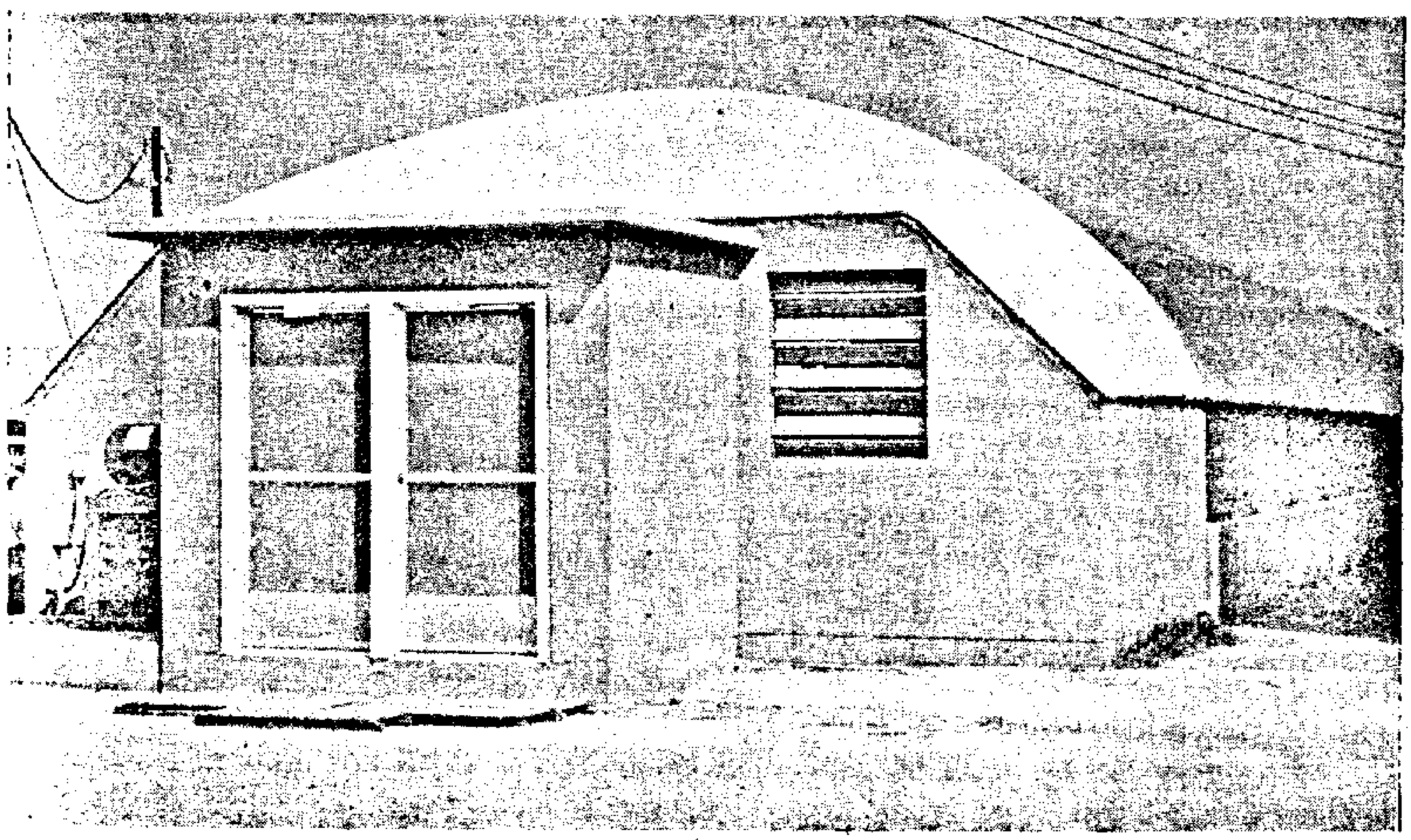
We have experimented with several methods of removing particulate matter and have found that simple sedimentation is the simplest and least expensive of those methods tested. Modifications of the settling chambers are being tested to determine the most efficient design for our purposes.

Biological trickling filters with various substrates have been tested as well as a biodisk filter. A trickling filter being tested at present is the Pielkenroad filter which permits recovery of the sloughed biological growth from the filter. Eventually we hope to make use of this material as well as the particulate matter filtered from the water as part of foods for shrimp or for other marine animals.

To a limited extent the water treatment methods can be substituted for one another depending on the design of a particular system, the amount of sunlight available and desirable, and the various costs involved. In our system, which is housed in a greenhouse, we use full sunlight to encourage algal growth during the winter when solar heating is



The closed raceway system (shown above) is housed in an air-inflated greenhouse.



desirable and partial shading during the summer to reduce temperatures. The algal growth in the system is less during the summer, therefore expanded use of the trickling filter is required.

While the economic success of a closed system is dependent on improvement in our ability to supply the animal's nutritional needs, to control diseases, and to remove wastes efficiently, this appraoch offers some major advantages over culture under semi-natural conditions. Hopefully, research during the next few years will determine whether this approach will be an economically viable one for penaeid shrimp.